INTRODUCTION TO DOSIMETRY OF IODINE-131 (^{131}I)

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^{131}I is but one isotope of about 37 known isotopes of iodine. The isotopes of iodine have atomic masses from 108 to 144.

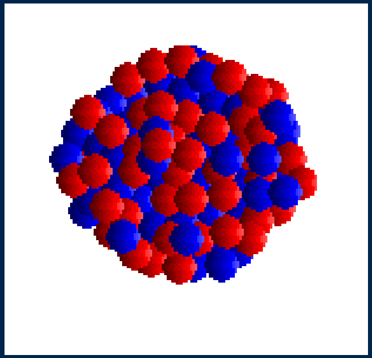
All are unstable against radioactive decay except ^{127}I.

Examples of Iodine Isotopes: ${}^{123}_{53}\mathrm{I}$, ${}^{124}_{53}\mathrm{I}$, ${}^{125}_{53}\mathrm{I}$, ${}^{126}_{53}\mathrm{I}$, ${}^{127}_{53}\mathrm{I}$, ${}^{128}_{53}\mathrm{I}$, ${}^{129}_{53}\mathrm{I}$, ${}^{130}_{53}\mathrm{I}$, ${}^{131}_{53}\mathrm{I}$, ${}^{132}_{53}\mathrm{I}$

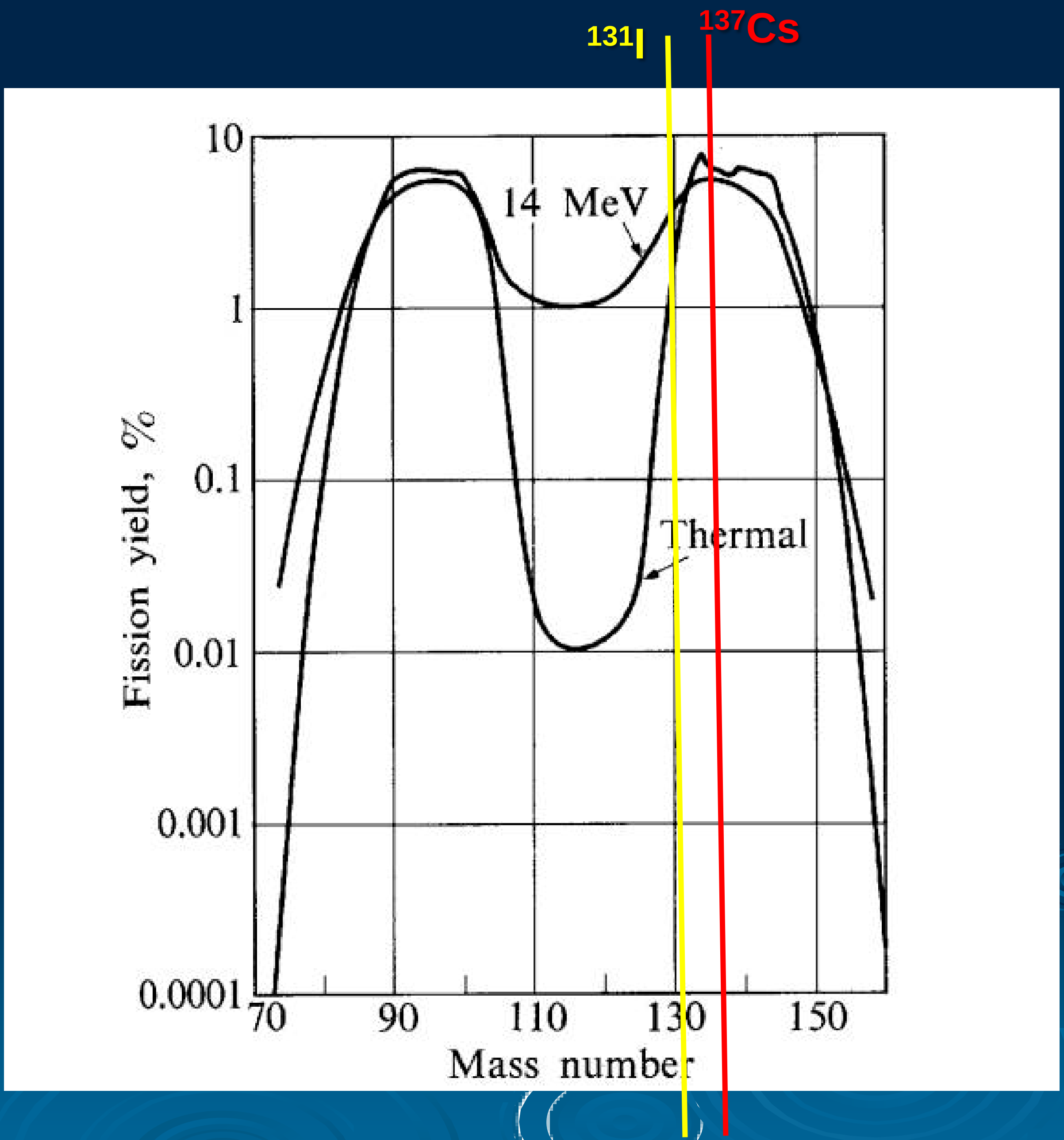
Q: Where do we get I-131?

(where do we get any radionuclide?)

A: In this case, from fission of uranium which creates intermediate size mass products, primarily with masses of 90-100 and 130-140.



Fission yield of ^{131}I is about 2.8%



Most all of the iodine isotopes (except for a few meta-stable states) decay by positive or negative beta decay.

We will only review negative beta decay here because that is what is relevant to ^{131}I.

Negative beta decay: the decay of a neutron into a proton, which remains in the nucleus, and an electron, which is emitted as a beta particle

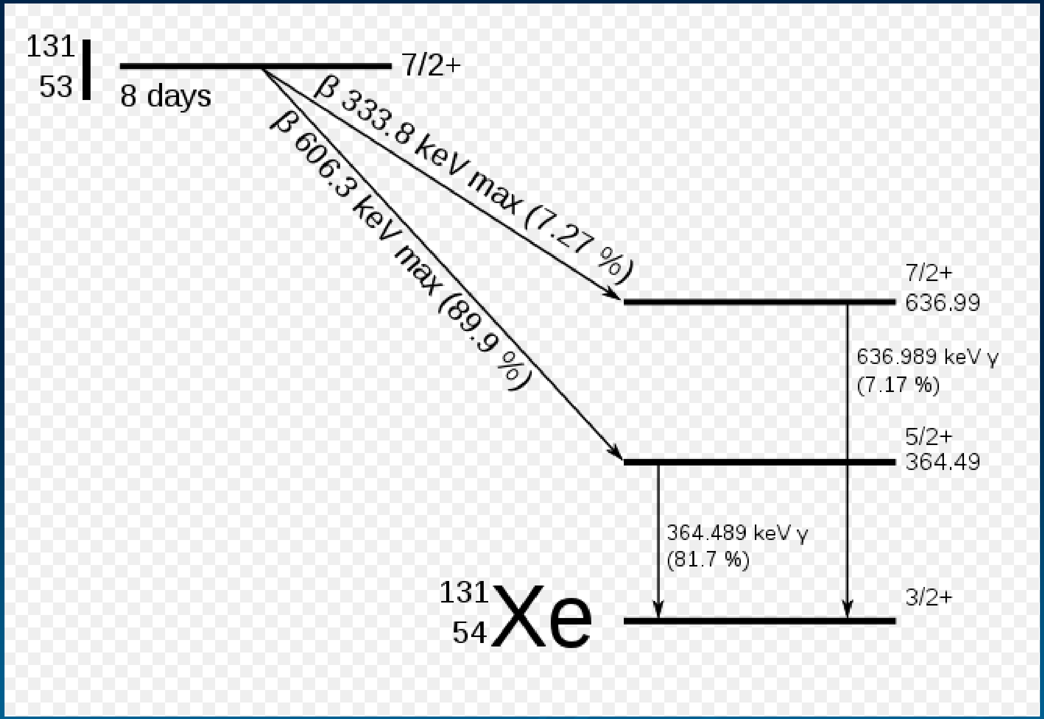
$$^{131}_{53}I \rightarrow ^{131}_{54}Xe + ^{0}_{-1}e$$

The Q value, or energy released from β^- decay is primarily the difference in the rest masses of iodine and its decay product, xenon.

Q_β = 970.8 keV (average energy of beta particles is about ~183 keV)

Half-life of ^{131}I about 8.02 days.

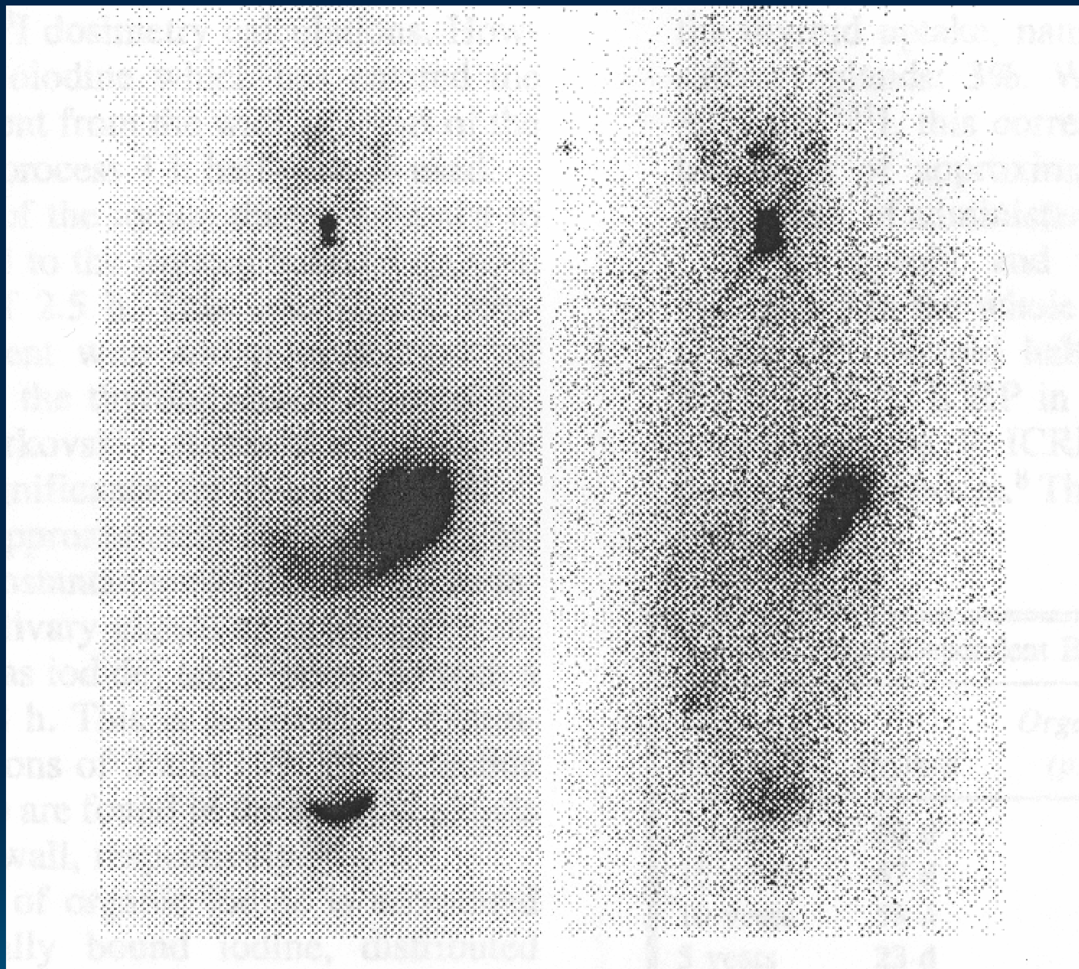
There are several beta-decay possibilities, each with their own probability of decay. The most important parts of the decay scheme are shown below.



Gammas from ^{131}I (8.02)

Eγ (keV)	Iγ (%)	Decay mode
80.185	2.62	β^-
85.9	0.00009	β^-
163.93		β^-
177.21	0.270	β^-
232.18	0.0032	β^-
272.50	0.0578	β^-
284.31	6.14	β^-
295.8 *2*	0.0018	β^-
302.4 *2*	0.0047	β^-
318.09	0.0776	β^-
324.65	0.0212	β^-
325.79	0.274	β^-
358.4 *2*	0.016	β^-
364.49	81.7	β^-
404.81	0.0547	β^-
503.00	0.360	β^-
636.99	7.17	β^-
642.72	0.217	β^-
722.91	1.773	β^-

Whole-body nuclear medicine scan showing iodine gamma emissions



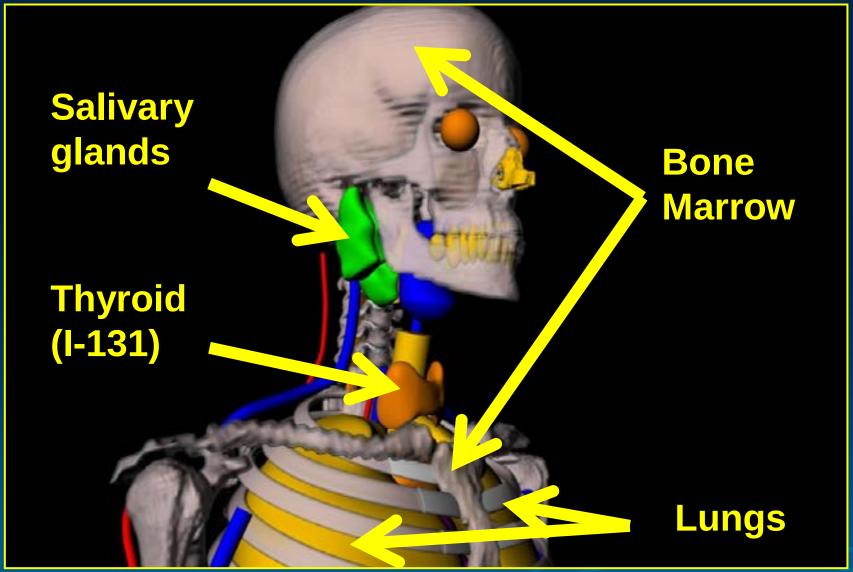
^{123}I ($t_{1/2}$=13.2 h) at 4 and 24 hr after injection (158 keV γ)

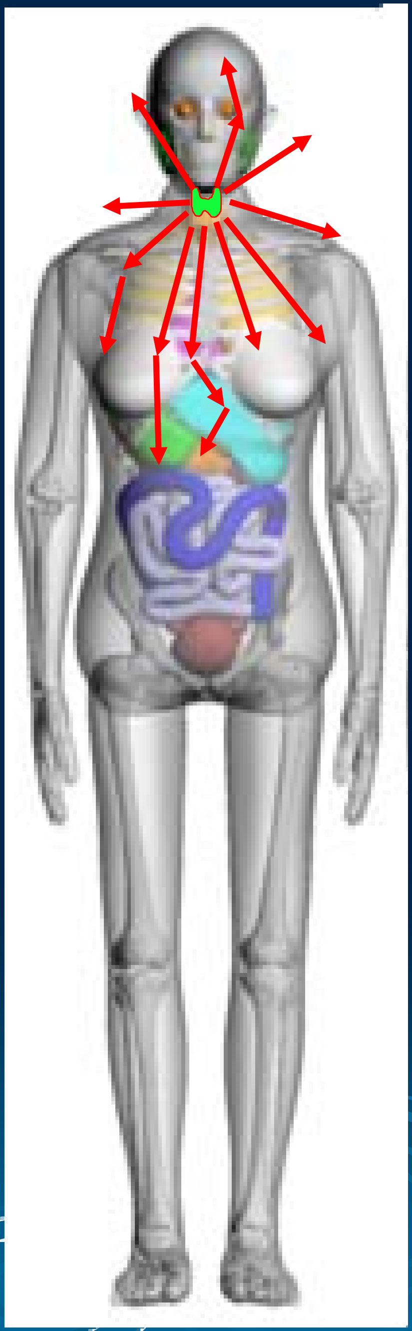
What does this image suggest to us?

- Where activity is located that contributes to the image.
- Where activity is located that might expose nearby organs.

The thyroid gland receives self-dose from activity it concentrates as does the salivary glands, stomach wall and bladder.

Other organs are primarily receiving “cross-fire” dose – photons emitted from the thyroid and to a lesser degree, from the organs listed above.



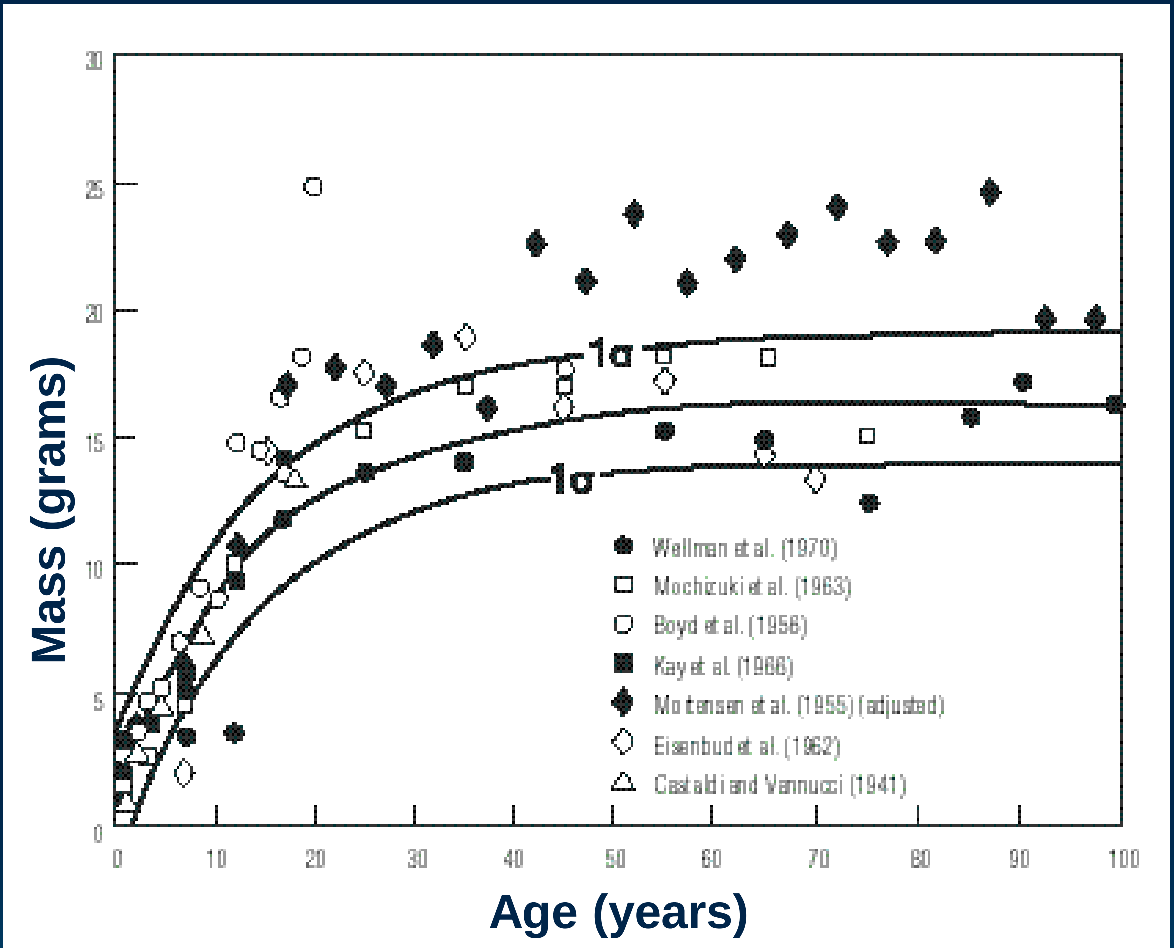


Figures courtesy of S. Lamart and C. Lee (NCI)

Some typical assumptions that affect the estimated dose to the thyroid:

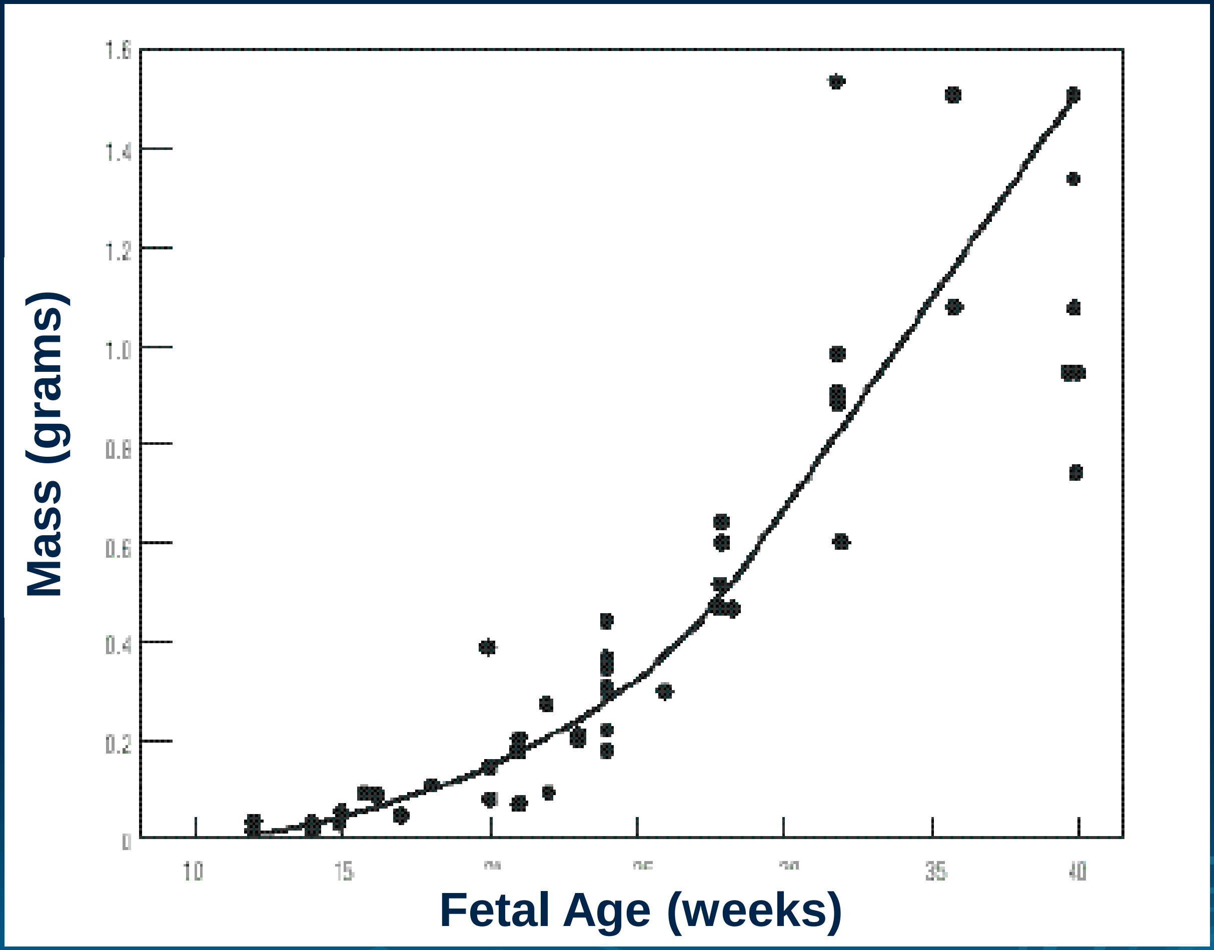
1) The kinetic energy of beta particles and photons <10 keV are fully absorbed in the target organ.
2) The fractional uptake by the gland is a specific % (e.g., 25-30%) after a specified age.
3) The normal inventory of stable iodine (^{127}I) in their thyroid which is about 10 mg for the adult. In countries where stable iodine intake is low, a physiologically-based increase in thyroid mass usually occurs (sometimes resulting in goiters).
4) If stable iodine inventory is low, additional uptake of radioiodine may take place but is generally compensated by the increase in mass.
5) The retention of iodine in the thyroid gland follows a 2-component exponential loss. The "apparent" retention half-time in adults is assumed to be 80 days, and 15, 20, 30, 70 days for 3 months, 1 yr, 5 yr, 10yr old children, respectively.
6) Thyroid mass is approximately predictable based on age - though uncertain on an individual level.
7) Absorbed dose within the thyroid gland is approximately (though not entirely) uniform.
8) Doses received by other organs from radioiodine may be small in comparison to the thyroid but may be significant if there is large administered activity

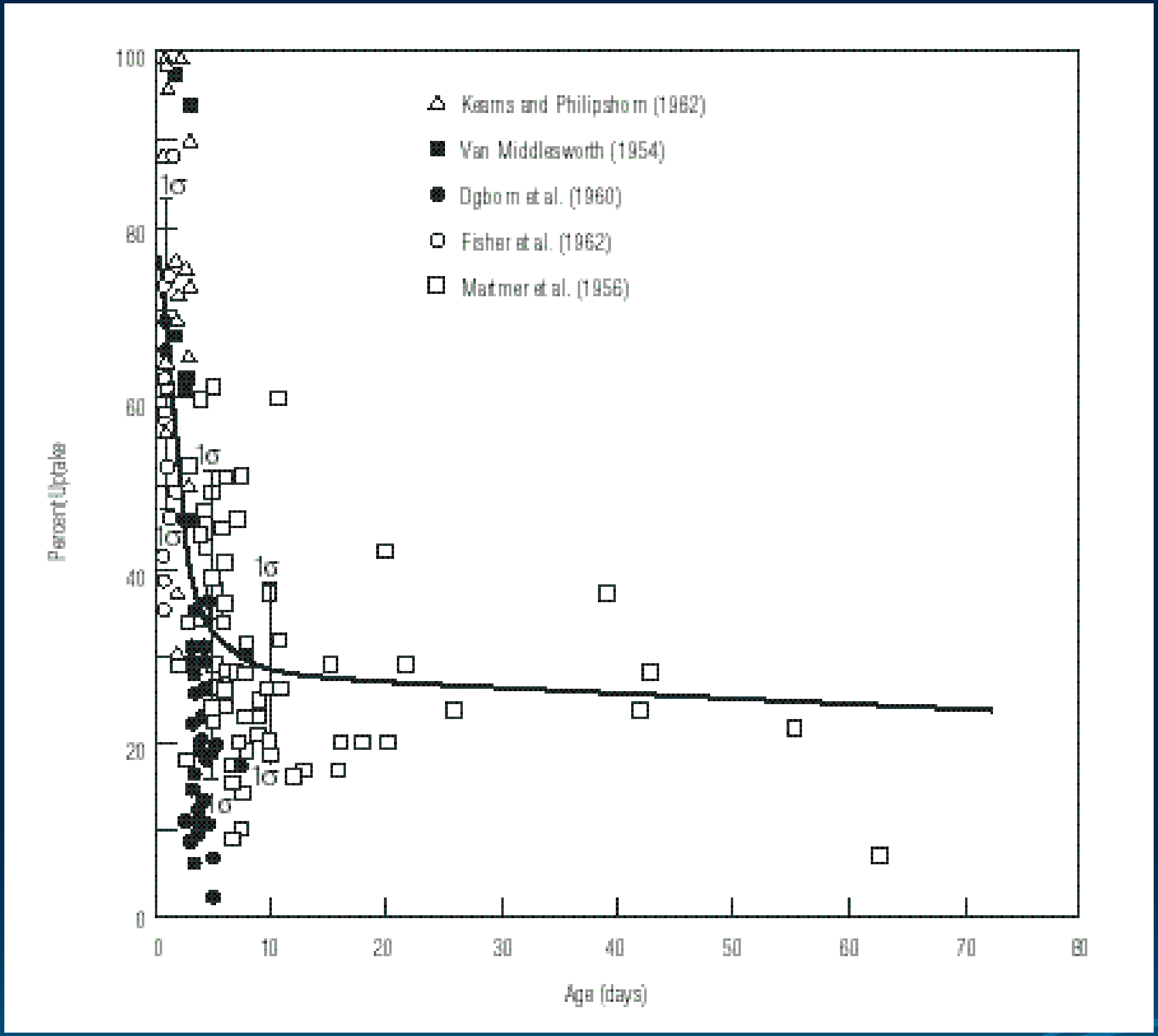
Some of the data



Thyroid gland mass as a function of age. Adapted from Wellman et al. (197) by NCI (1997). This is older data but still very applicable.

When in utero exposure takes place, parameters for the fetus must be used. Here the fetal thyroid gland mass as a function of gestation age is shown NCI (1997). Again, older but still generally applicable.





Thyroid uptake as a function of age shortly after birth (NCI 1997 from many sources). Note that the mean value of uptake depends greatly on the dietary iodine status of the population surveyed.

In the estimation of organ doses from internal irradiation, the time-dependence is determined by the biokinetic model and how activity accumulates in each organ as a function of time. The age dependence is primarily a function of age and organ size.

Published values (ICRP 1989) of absorbed dose per unit activity intake are shown

Absorbed Dose (Gy) Received per Bq of ^{131}I Ingested for Selected Organs

ORGAN	3 mos	1 Year	5 Year	10 Year	15 Year	Adult
Bladder wall	3.70E-10	2.40E-10	1.30E-10	7.30E-11	4.50E-11	3.80E-11
Breast	5.60E-10	4.10E-10	2.30E-10	1.50E-10	7.30E-11	5.80E-11
Stomach wall	3.40E-09	2.00E-09	9.80E-10	5.6E-10	3.80E-10	3.00E-10
Liver	4.60E-10	3.20E-10	1.70E-10	9.8E-11	5.90E-11	4.70E-11
Ovaries	3.90E-10	2.70E-10	1.40E-10	7.80E-11	4.70E-11	4.00E-11
Testes	3.40E-10	2.30E-10	1.10E-10	6.60E-11	4.00E-11	3.40E-11
Thymus	2.30E-09	1.70E-09	8.50E-10	4.70E-10	2.30E-10	1.50E-10
Thyroid	3.70E-06	3.60E-06	2.10E-06	1.10E-06	6.90E-07	4.40E-07

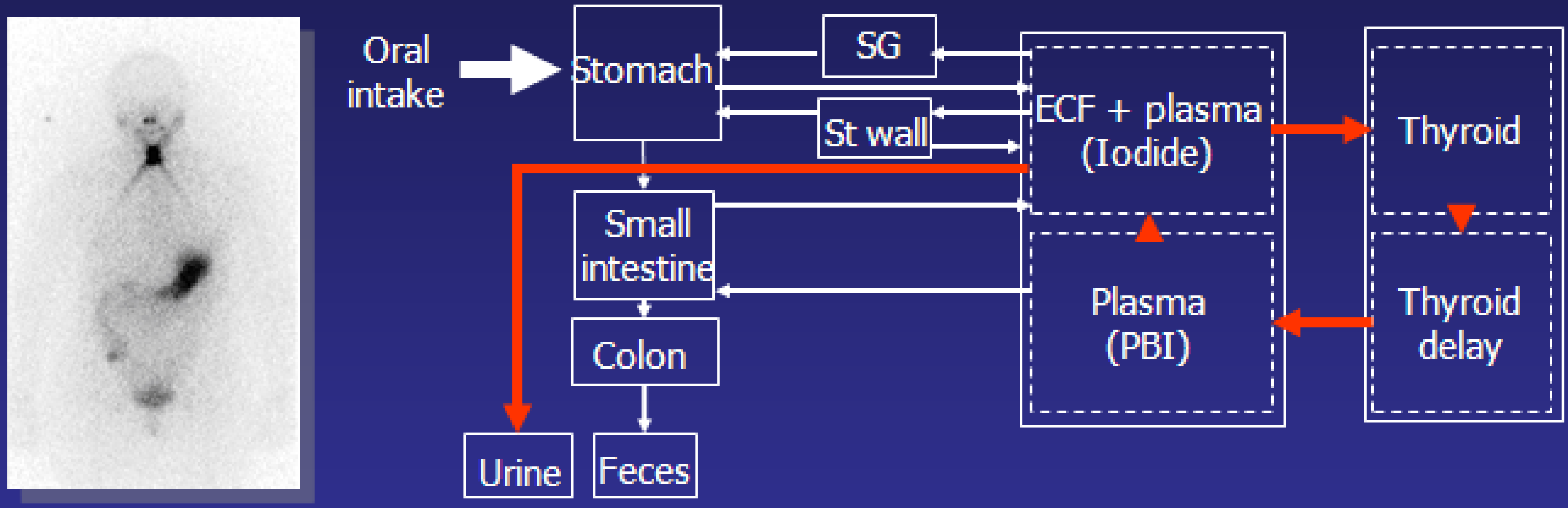
It's important to note that dose estimation for ^{131}I treatments sometimes require non-standard assumptions.

For example, NCI is highly involved in reanalysis of the **Thyrotoxicosis Therapy Follow Up Study (TTFUS).**

This study is of the mortality risk related to doses delivered to hyperthyroid patients as a result of ^{131}I treatment:

- 23,020 patients
- Adults, 80% of female
- Estimates of radiation dose to every major organ from ^{131}I

Hyperthyroid patients have much faster physiologic processes and, hence, the kinetic behavior of iodine in these patients is faster. Biokinetic models, on which dosimetry is based, must be calibrated to actual measurements of hyperthyroid patients.

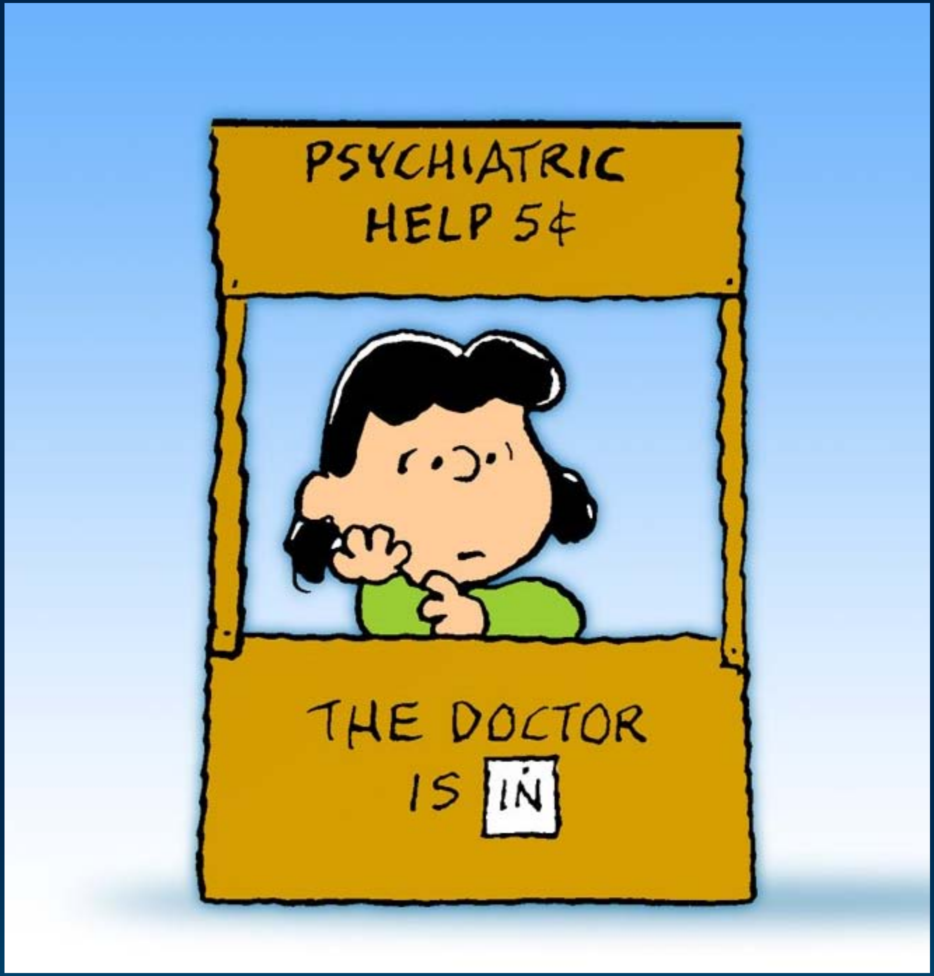


- Transfer rates derived from data of 143 patients

Data and diagrams courtesy of D. Melo (NCI)

Preliminary dose calculations (courtesy of D. Melo) for hyperthyroid patients and comparisons with calculations using standard dose coefficients,

Organs	Average doses (Gy)		
	Current methodology	ICRP 53 methodology	Current/ ICRP 53
Thyroid	1.1×10^{2}		
Salivary glands	**2.3×10^{0}**		
Breast	3.2×10^{-2}	3.0×10^{-2}	1.1
Lung	7.0×10^{-2}	5.0×10^{-2}	1.4
Red Marrow	4.9×10^{-2}	4.0×10^{-2}	1.2
Stomach wall	**1.2×10^{0}**	**1.8×10^{-1}**	**7**
Urinary bladder	**3.8×10^{-1}**	**1.3×10^{-1}**	**3**
Pancreas	**4.2×10^{-2}**	**2.3×10^{-2}**	**1.8**
Ovaries	1.1×10^{-2}	1.6×10^{-2}	0.7
Uterus	2.2×10^{-2}	1.8×10^{-2}	1.2
Colon	1.6×10^{-2}	1.9×10^{-2}	0.8



Alina Brenner is now going to explain about risks of I-131 in medicine.